PROGRESS REPORT

AN EFFECTIVE SURROGATE FOR IMPACT STUDIES

(MEDICAL ASPECTS)

PREFATORY ABSTRACT

Unembalmed (fresh) cadavers were used to test
restraint systems in automobile impact studies. Some
cadavers were mounted in a rearward firing sled, others
were placed in standard cars during collisions.

19 subjects were used in 21 experiments. Prior
to testing the specimen was evaluated, including
extensive x-ray studies. After each experiment the
subject was re-examined including repeat x-rays and
where indicated, additional views were made. A post-
mortem examination was then performed.

During each test 4 high speed cameras, 1250 frames
per second, were used on board. Multiple telemetric
recordings were made for later analysis.

The radiographic and gross pathologic changes
were similar to patients seen following high velocity
accidents. The results were compared with those of
car accident victims admitted D.O.A. in one of our
hospitals. For the test subjects all pertinent physical
and telemetric data was available, the D.O.A. subjects
are evaluated without this data.

This is a progress report and the information should
eventually aid in care of crash victims. The results
are being used to improve existing restraint systems
and to test experimental models.

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PROGRESS REPORT

AN EFFECTIVE SURROGATE FOR IMPACT STUDIES

(MEDICAL ASPECTS)

David L. Berens, M. D., George J. Alker, Jr., M. D.,

Harold Brody, M. D., Chester Glomski, M. D.,

*Michael Walsh, *W. Levan, Luis A. Valenzuela, M. D.

S. U. N. Y. at Buffalo, New York

*Calspan Corporation, Cheektowaga, New York

Presented by David L. Berens, M. D.

The committee on Medical Aspects of Automotive Safety in 1972 made this statement "automotive engineers are primarily interested in energy dissipation or the amount of force required to produce a given injury. Physicians on the other hand, tend to think in terms of length of treatment, impairment, and threat to life as critical factors in evaluation of an injury"[2]. The above statement is relative to my position as an active, practicing Radiologist in a clinical setting. We have the opportunity to see and study radiographically and by other means many victims of high speen accidents. I do not have the engineering background that many in this room have and my interest as a physician is quite different, however our goal is the same. We all are here to exchange ideas for the overall good of the patient and/or potential accident victim. I should like to stress the medical aspects rather than the many measurements that are being presented today by others.

We feel that the use of relatively fresh cadavers is the most effective surrogate for impact studies at this time[4]. There is no question that all of the

external measurements can be made on humanoids. In
addition to external measurements we are able to make
certain dynamic internal measurements such as a
simulated blood pressure and endotracheal (lung)
pressure.

The soft tissue in the cadaver is the most impor-
tant element to observe. One is familiar with the
discussion of fractures, dislocations, etc. We must
however look to the soft tissue injury whether it be in
the central nervous system, lung, heart, abdomen, etc.
for the very serious injuries. In the A. I. S. ratings
these are relatively well outlined. In my discussion
I will attempt to stress the medical aspects including
soft tissue changes and note where possible those that
can be determined by radiographic studies.

Our subjects were 19 in number, 17 males and 2
females. Two male subjects were used twice, therefore
there were 21 experiments. The average weight for the
males was 164.2 lb., for the females 140 lbs. This
statistic is relatively poor because of the limited
number. The overall average weight for the entire group
was 161.7 lb. The average height for males was 5 ft.9½ in.
Female average height 5 ft.7 in. The overall average
height was 5 ft. 9¼ in. The male average age 57.2 years,

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female average age 41. The overall average age 55.5 years.

Of the 21 experiments 9 were done on a sled and 12 auto impacts. Of the 12 impacts 9 were considered as drivers and 12 as passengers.

RESTRAINTS

Bags were used in 11 experiments, 8 experiments were carried out with 3 point lap and shoulder restraints and 2 had no restraint.

METHOD

Prior to the impact experiments the subject was inspected for physical signs of injury, disease and other abnormalities. Physical measurements such as height, weight, etc. were recorded.

Measuring devices were then placed circumferentially on the cranium, the thoracic spine, ribs and 1st sacral segment. These have been described.

A foley, usually 12 Fr. catheter was placed via the left femoral artery in the abdominal aorta and the balloon inflated. A transducer was placed in the left common carotid artery. 250 ml.of Gelgard M was introduced via the catheter into the aorta and a diastolic pressure maintained at approximately 70 to 90 mm. of mercury.

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A Foley catheter was introduced into the trachea and the balloon insufflated. 1,200 cc. of air were introduced giving relatively good aeration and visualization of the tracheobronchial tree and alveoli. The endotracheal pressure was maintained at approximately .25 lbs. per square inch to record dynamic pressure during the test run.

The subject was then clothed in the prescribed manner and radiographic studies were carried out. The subject was x-rayed using standard radiograph equipment in a hospital setting and the views carried out similar to an injured patient. The radiographic studies were done by qualified hospital radiologic technicians under the supervision of the Radiologist. Examinations included multiple views of the skull, cervical spine, thoracic spine, lumbosacral spine, pelvis, chest, (including rib detail), abdomen and femora. In certain instances extremities were examined.

Following the experiment the subject was re-x-rayed in a similar manner. Where indicated, additional areas were examined and additional views made in order to elicit specific radiologic findings.

Both sets of examinations were then viewed; a full report made which included comparison of the two studies. The Radiologist should be able to draw certain conclusions as he would with any patient. Also, the radiologic changes should be helpful to the Pathologist who is then going to examine the patient further.

The subject was then re-examined for physical signs of trauma and other changes. A Physician, preferably a trained Pathologist does a careful post-mortem study. This was usually gross observation, however, blocks of tissue were removed when indicated. Microscopic sections of the latter were made when necessary. These were reviewed later. The Pathologist concluded his complete report with a list of anatomic diagnoses including injuries and other findings.

At the 1974 meeting of this group, guidelines for future research, a statement was made to find out the correlation between living humans and cadavers by means of real accident situations. We are attempting to do this by comparing these test subjects with those admitted to a specific hospital where similar physical and radiologic examination is carried out as well as post-mortem examination.

Patrick[3] in his paper "Unembalmed Cadaver Trauma Study" in 1974 reported in I.R.C.O.B.I. that the results were remarkably life-like.

"Their dynamics were very similar to human volunteers. The contusions of soft tissue, etc. were very similar. Organ similarity; he suggested that pressurization, etc. might be carried out." Injuries to the neck were noted only under severe conditions. He also stated that they were more prevelant than those of accident population and this might be due to muscle tone.

In a paper by Alker, Jr.[1] a review of 146 postmortem radiographic examinations performed on victims of fatal accidents indicated that skull fractures were found in 61 examinations and fractures of the cervical spine were found in 32. These were patients brought in D.O.A. Some were passengers, others were pedestrians, bicycle riders, etc.

We have in general followed the protocol set up by Patrick[3]. On all of our subjects Walsh gave A.I.S. and other ratings to indicate severity of injuries. In one specific subject Calman II[4], a humanoid of approximately the same weight was run with the same experiment.

The measurements were somewhat different and the response of the cadaver to impact was considerably different than the humanoid. In all of the automobile crash testing where vehicles were used, humanoids were also used in the experiments simultaneously.

A review of what literature is available and in the progress reports, I have been able to find descriptions of some of the material which we are to present.

Other authors have stated the remarkable life-like dynamics, but in the past x-ray has been assigned to determine if fractures were present and very little else.

The soft tissue changes may include air in the subarachnoid space of the cranial vault, air in vessels, pneumothorax, pneumomediastinum, pneumopericardium. We have also been able to determine if unusual collections of fluid as well as air were in abnormal situations. Displacement of organs is a very important radiographic finding. The Radiologist can very quickly determine whether a pneumothorax is of the tension type which is serious, versus a simple non-tension pneumothorax. Fractures of certain bones in specific sites may suggest underlying soft tissue change such as laceration of liver, kidney, etc. This has been referred to as a circumstantial lesion by Fayon, et al. It must be recognized however, that blunt trauma to the abdomen or the chest with or without fracture may cause rupture of solid organs or

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even hollow viscera without actual penetration by bone
or other sharp objects.
                1
Alker Jr. stated it is particularly the fractures
and dislocations of the cranio-cervical junction and
upper cervical area where the Radiologist is of greatest
help to the "forensic Pathologist".

On x-ray studies of our subjects we have identified
skull fractures, cervical spine fractures, subluxation
and dislocation. Fractures of ribs, sternum, transverse
processes, pelvis and extremities were noted. Pneumothorax,
tension and simple were noted, pneumomediastinum and pneumo-
pericardium were demonstrated. Fractures, even multiple
rib and sternum fractures are not necessarily of serious
consequence. A unilateral tension pneumothorax of a severe
degree may be life threatening, bilateral pneumothorax is
of course, very serious. Pneumopericardium usually means
very extensive injury, life threatening and possibly
impending death such as would occur with transection of
the root of the aorta. Widening of the mediastinum
would indicate rupture of the aorta and/or other great
vessels in this area which have a very grave prognosis.
In a live subject prior to injury but D.O.A. air within
the great vessels and/or heart would indicate air embolus

which is usually fatal.

In a clinical setting the physical examination, blood pressure, laboratory studies and x-ray studies would allow us to determine the site and extent of most injuries. The cadaver in these experiments reflect similar changes, of course we are not able to evaluate vital signs or laboratory work.

My fellow physicians have challenged the use of the cadaver stating that the lack of muscle tone and the normal reflex action of the patient is lost. Previous experiments have shown that as far as reflex action, there is not sufficient time even at 30 mph collision for the patient to react. Also it has been demonstrated that beyond 12 to 15 g force, the subject is overwhelmed and loses the ability to maintain muscle control. The time interval is so short and the g force so great, this in effect renders the living subject simply a body being hurled about passively without control.

The following are illustrative examiples taken from Alker's 146 D.O.A. subjects and compared with examples of our 19 subjects.

Fig. 1

Indicates the head and neck injuries in the Alker series.

Fig. 2

Illustrates the so-called "hangman's fracture, involving the posterior elements of C2 due to hyper-extension. There is anterior subluxation on C2 on 3.

Fig. 3

Fracture through the base of the odontoid process with anterior subluxation. This type of injury is due to flexion and allows the posterior aspect of the body of C2 to impinge upon or literally sever the cord at this very high level.

Fig. 4

An AP view of the cervical spine showing air in the vessels of the neck. This would indicate air emboliza-tion which would cause death.

Fig. 5

An AP view of the chest showing air in the great vessels due to embolization and this would give rise to death.

Fig. 6

An AP view of the chest showing air in the heart which is similar in origin and outcome to the two previous cases.

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Fig. 7

Tension pneumothorax right and pneumomediastinum.

Fig. 8

A lateral view of the cervical spine with the neck in slight flexion. This is a normal subject and illustrates some of the important anatomy. One should observe the size and configuration of the vertebral bodies as well as their alignment. Notice the potential space for the cord posteriorly. The soft tissue is outlined by air in the nasopharynx, oropharynx, hypopharynx and trachea. This is very important and the distribution of this air is extremely important in determining whether there has been a laceration in this area or abnormality such as edema or hemorrhage has occurred in this vicinity which is often life threatening since it may obstruct the trachea.

Fig. 9

This was our 1st test subject Calman 1* showing the routine lateral study of the cervical spine. Note that the alignment at the level vertebral body C6-7 is relatively normal. This radiograph was taken after the rest run.

Fig. 10

The cervical spine is in extension, note the wide gap between the vertebral bodies C6-7 which would indicate a severe injury to the soft tissue in this area as well

*Calman is a generic term for the cadavers used at Calspan.

as fracture of the posterior elements. This was a hyper-
extension injury. These 2 slides illustrate the impor-
tance of proper positioning to demonstrate actual pathology
on the radiograph.

Fig. 11

Our 3rd subject demonstrating a fracture at the base
of the odontoid process. This is shown in slight flexion
and is somewhat similar to those in the Alker group.

Fig. 12

Our 7th subject after a 2nd experiment in which
there was a disatrous impact with fracture, dislocation
at the C4-5 level. This is taken with the neck in
flexion and there would be complete disruption of the
cord at this level. Notice that the air in the soft
tissue is displaced somewhat anteriorly.

Fig. 13

With the neck in extension one can see the wide gap
which measured 6 to 8 cm.

Fig. 14

An AP view one can also recognize the wide gap between
the 2 vertebral bodies. One should note the relative
normalcy of the trachea, it is not displaced. There is
soft tissue air, paravertebral on the left but this is
interstitial and not intravascular. In a cadaver one is
not able to demonstrate air embolization.

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Fig. 15

An AP view of the chest indicates fractures of the
left clavicle as well as ribs on the right. In a
limited study such as this it is very difficult to rule
out multiple fracture of ribs. There is interstitial
air in the left axillary region which may simply represent
extravasation from the intrathoracic region. This usually
accompanies pneumothorax secondary to chest trauma with
or without rib fracture. Note the endotracheal tube with
the balloon inflated. Also the catheter containing the
transducer in the left carotid artery.

Fig. 16

The same patient, an AP view of the chest taken for
greater detail of rib, etc. There is an extensive amount
of air in the pericardial sac indicating pneumopericardium.
This is very serious in that it indicates tremendous trauma
to the chest. In this instance the patient has a transec-
tion of the root of the aorta complete, which would give
rise to death almost instantly. During the experiment,
this patient's relative blood pressure ran up over
1,980 mm. of mercury at which time there was a precipi-
tous drop (see figs. 17 and 18). Then the simulated
blood pressure started to rise somewhat. The soft tissue
change is far more important than the fractures.

Fig. 17

Timed frame sequences of impact study of Calman 3.
There is severe flexion of neck at maximum force (frame 5).
There was no contact with solid object.

Fig. 18

Graph of aortic pressure of Calman 3 which reached
1,980 mm. of mercury and then dropped precipitously.
There was an extensive rupture at the root of aorta.

Fig. 19

Photograph of ruptured root of aorta held between
fingers.

Fig. 20

An AP view of the chest indicating a tension
pneumothorax on the right. There are literally no lung
markings here. The trachea, heart and mediastinal
contents have been displaced to the left. The right
hemidiaphragm is depressed.

Fig. 21

Another view, same subject, marked tension pneumo-
thorax on the right. Notice the rib fractures. Endo-
tracheal balloon is in position. This is a better view
of the posterior ribs on the right of the same subject
showing the multiple rib fractures posteriorly through

the neck of each rib. Fractures are also noted laterally
as marked 6 and 7. The posterior rib fracture is usually
one sustained with severe trauma, also the 1st rib when
fractured usually requires very extensive trauma. The force
required to give rise to rib fractures of the 1st and/or
2nd ribs is far greater than the lower ribs. Also the
posterior rib fracture that is close to the articulation
with the transverse processes also requires much more
energy than those rib fractures which occur laterally
or anteriorly. It is very difficult to lump all rib
fractures together since there is considerable differ-
ential in force required to fracture different levels and
in different anatomical locations.

Fig. 22

An AP view of the abdomen showing the distended
balloon within the abdominal aorta. This has been
filled with contrast so that it can be seen on the
radiograph. In this instance there are multiple frac-
tures involving the pelvic bones bilaterally.

Fig. 23

A localized study of the lower thoracic and upper
lumbar spine. There are fractures transverse processes
on the right the 1st lumbar, and on the left the 2nd
lumbar. This type of injury requires a great deal of force.

Fig. 24

At post-mortem there was a large laceration of
the liver which extended approximately 7 in. across
the transverse diameter and penetrated 1½ to 2 in.
deep. This type of injury requires immediate surgical
intervention. The same patient had a tear of the
capsule of the spleen.

CONCLUSION

This is a report on work in progress and covers
19 subjects with 21 experiments. We have stressed the
medical findings and more specifically the radiologic
demonstration of certain lesions. I would like to
emphasize that the Radiologist can be a very important
member of the team in evaluation of subject injury.
The soft tissue is our prime concern. The fracture of
bone structure is important but very seldom is it a
matter of life and death. Frequently from the pattern
of bone injury one can ascertain or predict the under-
lying soft tissue pathology. We have made no attempt
to correlate or express the forces required in these
specific lesions, all of this data is available and will
be collated. Our fresh cadaver studies do show many of
the lesions that are found by x-ray and post-mortem
examination of accident victims who are D.O.A. and have
been examined in a similar manner. We are attempting
to follow through and will try to obtain the accident
records on the D.O.A. subjects for comparison. It would
actually be even more important to try and trace the non-
fatal accidents to determine if restraints have been

used and if so which type, speed of vehicle, etc.
Also, we could evaluate medically the type of treat-
ment as well as the outcome. This would allow us to
further evaluate the abbreviated injury scale, the
comprehensive research injury scale, and injury
severity score. We believe certain modifications
should be made. We would like to obtain as much data
as possible to reinforce any conclusions.

Once again, I would like to reiterate the place
of a trained and interested Radiologist assisting in
the evaluation of injuries sustained in experiments
using relatively fresh cadavers which in our opinion
is a most effective surrogate.

INCIDENCE OF HEAD AND NECK INJURIES

CASES WITH HEAD AND NECK INJURIES   144 (5~)

SKULL FRACTURES ONLY	86 (34.7%)	106 (42.7)	
SKULL AND CERV. SPINE INJ.	20 (8.1%)		
CERVICAL SPINE INJ. ONLY	38 (15.3%)	58 (23.3)	

CASES WITH NO HEAD OR NECK INJURIES   104 (42)

TOTAL   24~ (100)

Fig. 1   Statistics of head and neck injuries in

Alker Jr. series.

Fig. 2   Hangman Fracture.

Fig. 3   Fracture through base of odontoid process.
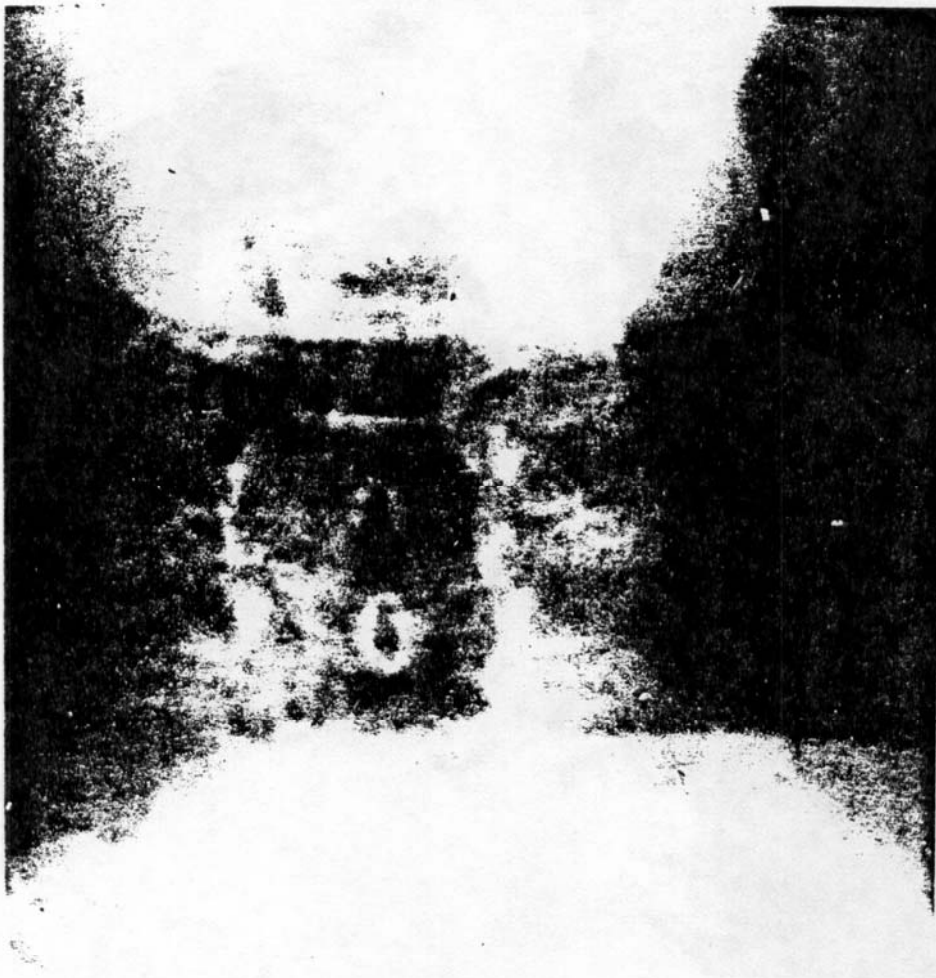
Fig. 4   Air in neck vessels, bilateral.

Fig. 6   Intracardiac air.

Fig. 5   Air in pulmonary vessels.

Fig. 8   Normal subject, lateral view of cervical region.

Fig. 7   Pneumomediastinum and pneumothorax.
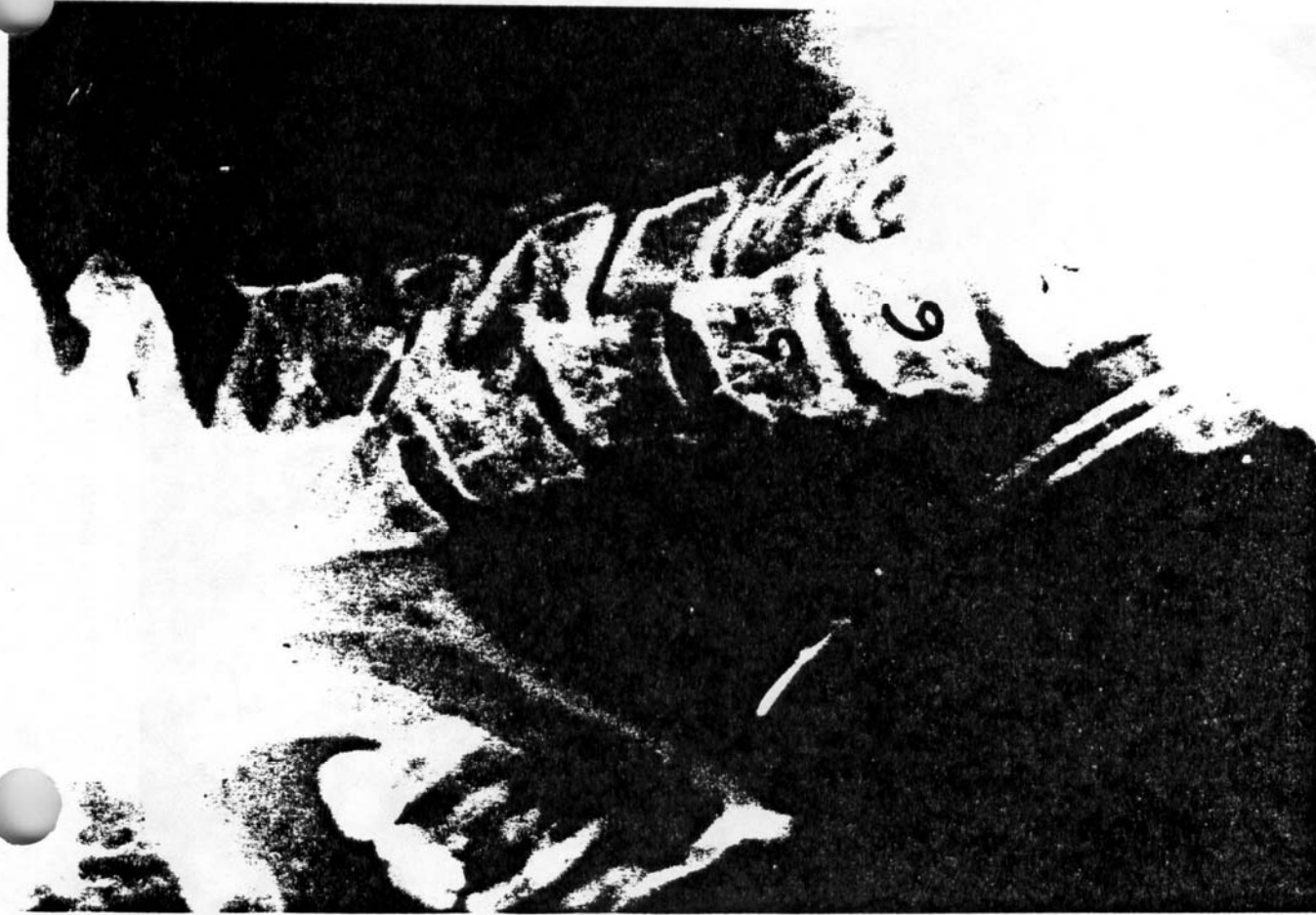
Fig. 9   Lateral study in flexion (Calman 1).   Fig. 10   Lateral in extension, injury at C6-7 level is now apparent (Calman 1).

*Calman is a generic term for the cadavers used at Calspan.
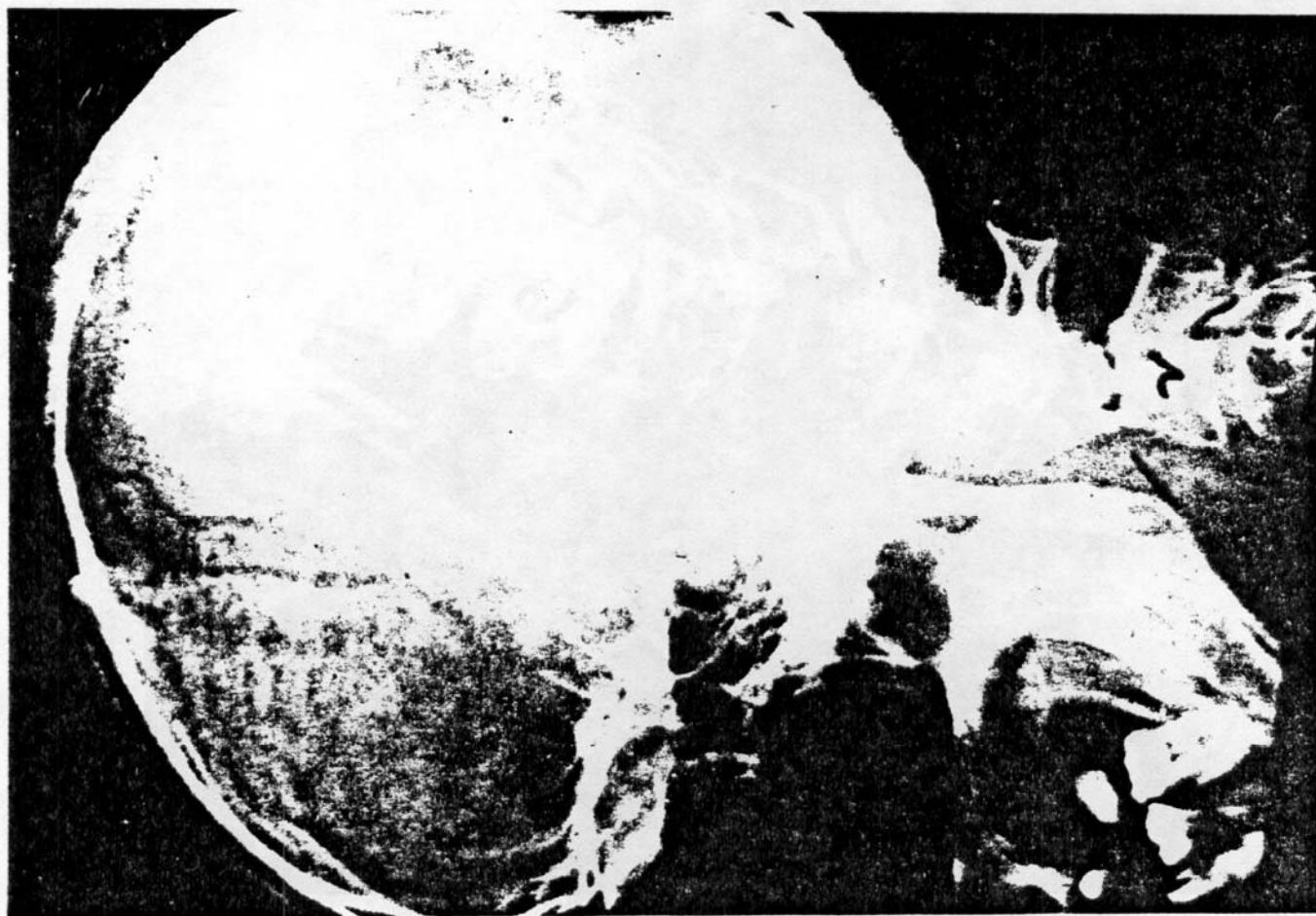
Fig. 11 Fracture base of odontoid (Calman 3)

Fig. 12 Fracture dislocation at 4-5 level (Calman 7B).
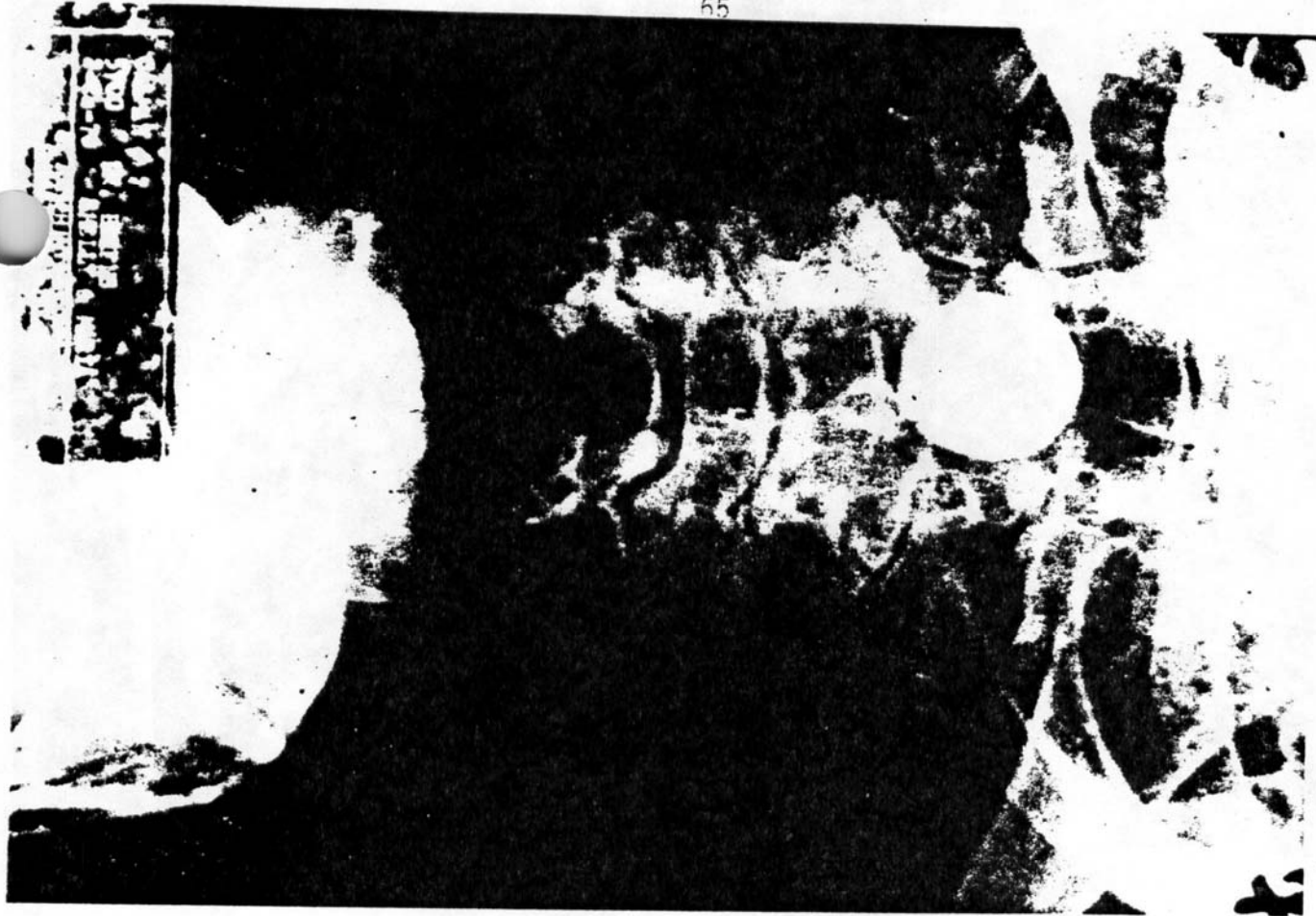
Fig. 14   AP view, same subject (Calman 7B).
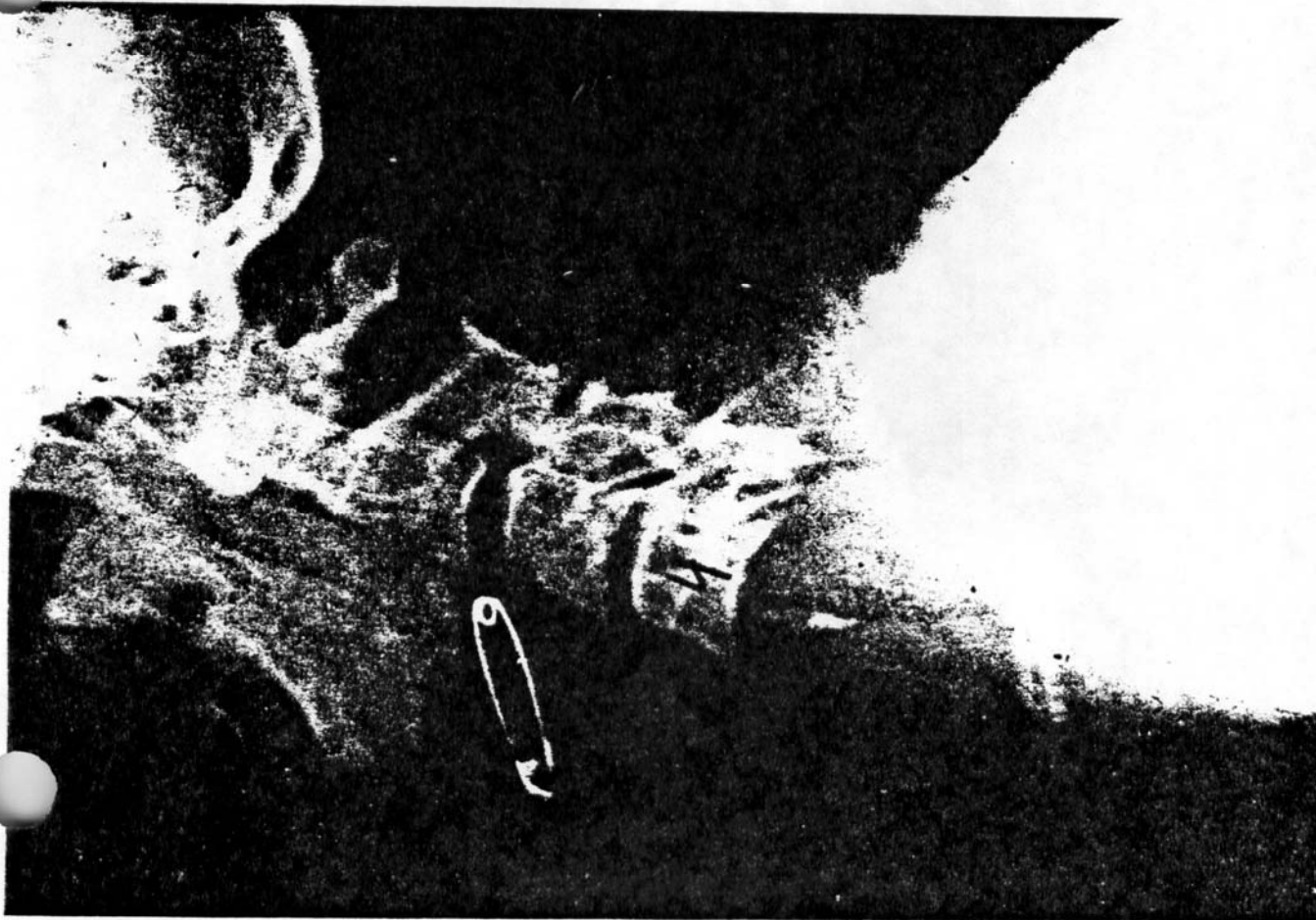
Fig. 13   Wide gap at 4-5 level in extension (Calman 7B).
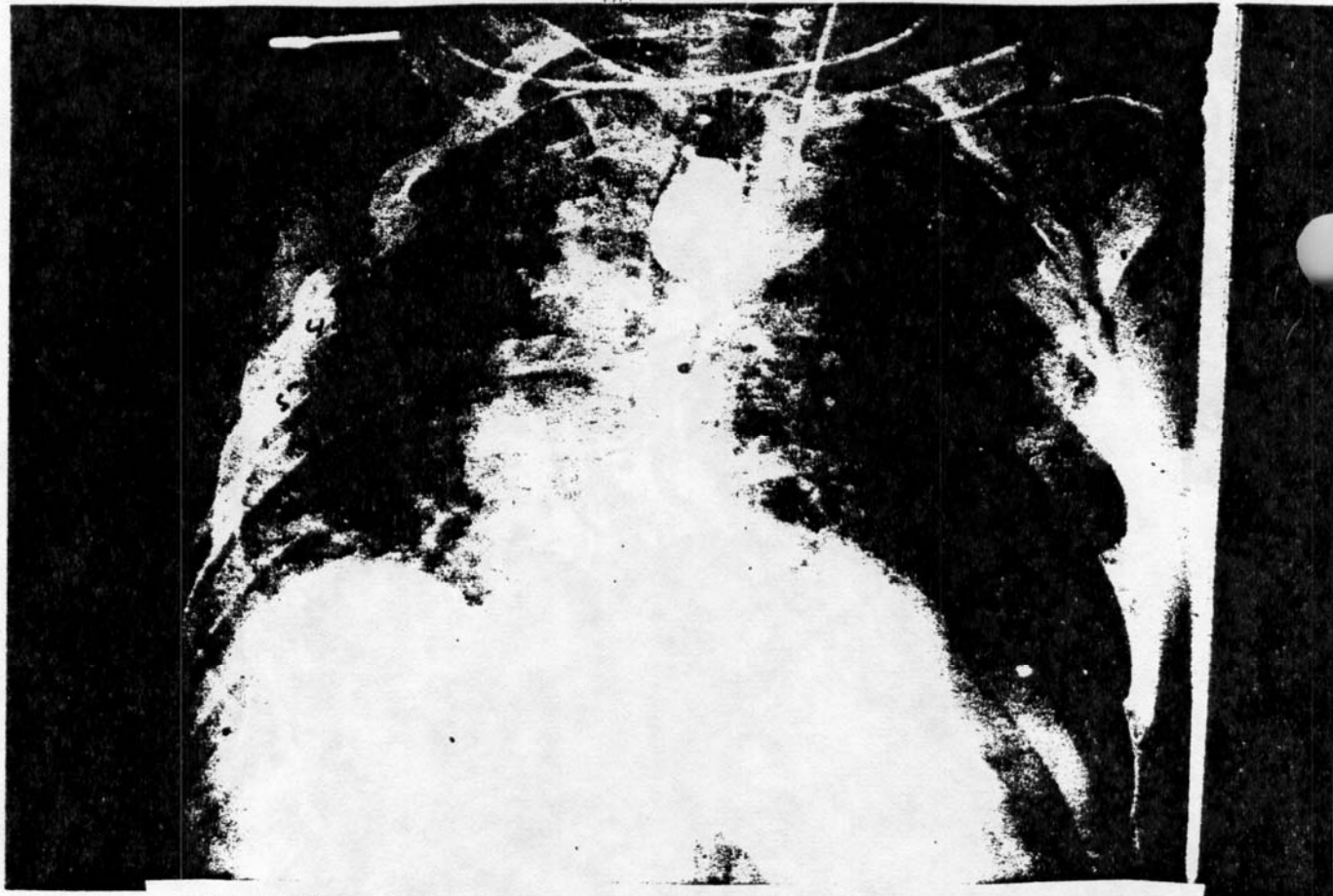
Fig. 15   AP chest, fractures of left clavicle and
right ribs (Calman 3).
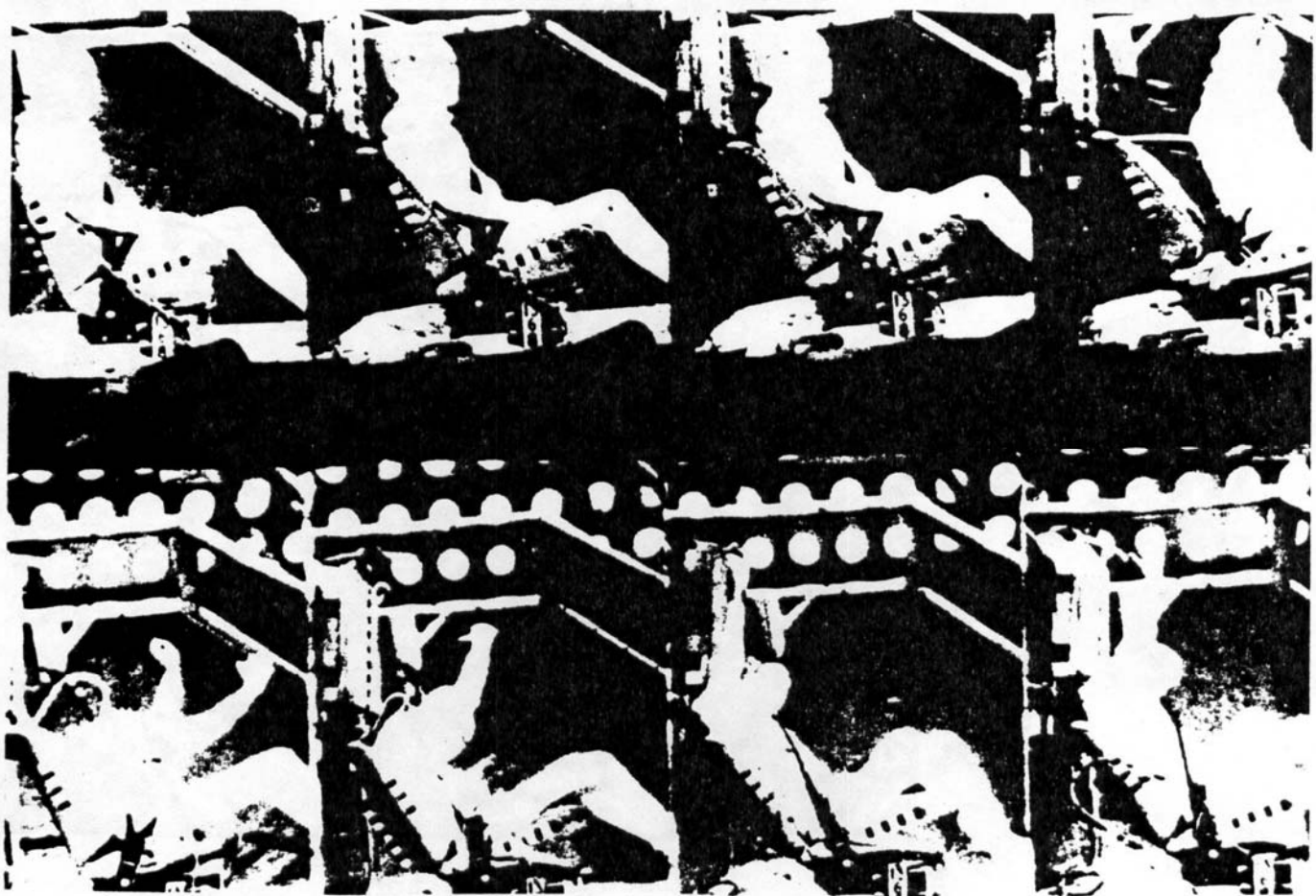

Fig. 16   Pneumopericardium (Calman 3).

Fig. 17   Timed sequence of Calman 3, figs. 15 and 16,
           note severe flexion of neck.

AORTA PRESSURE
CALMAN 3

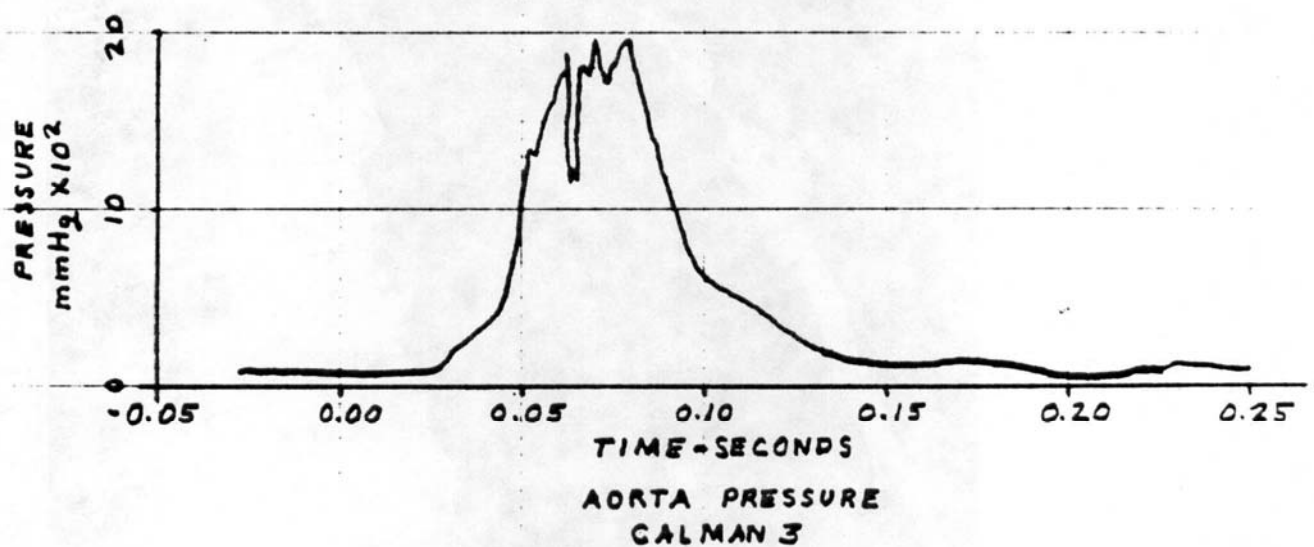Fig. 18   Graph of aortic pressure of Calman 3, note
           high pressure 1,980 mm. of mercury at peak
           stress.

Fig. 19   Avulsed root of aorta (Calman 3).

Fig. 20   Tension pneumothorax on right (Calman 13).

Fig. 22   Abdomen, pelvic bone fractures
(Calman 31).

Fig. 21   Close up view right pneumothorax, there are
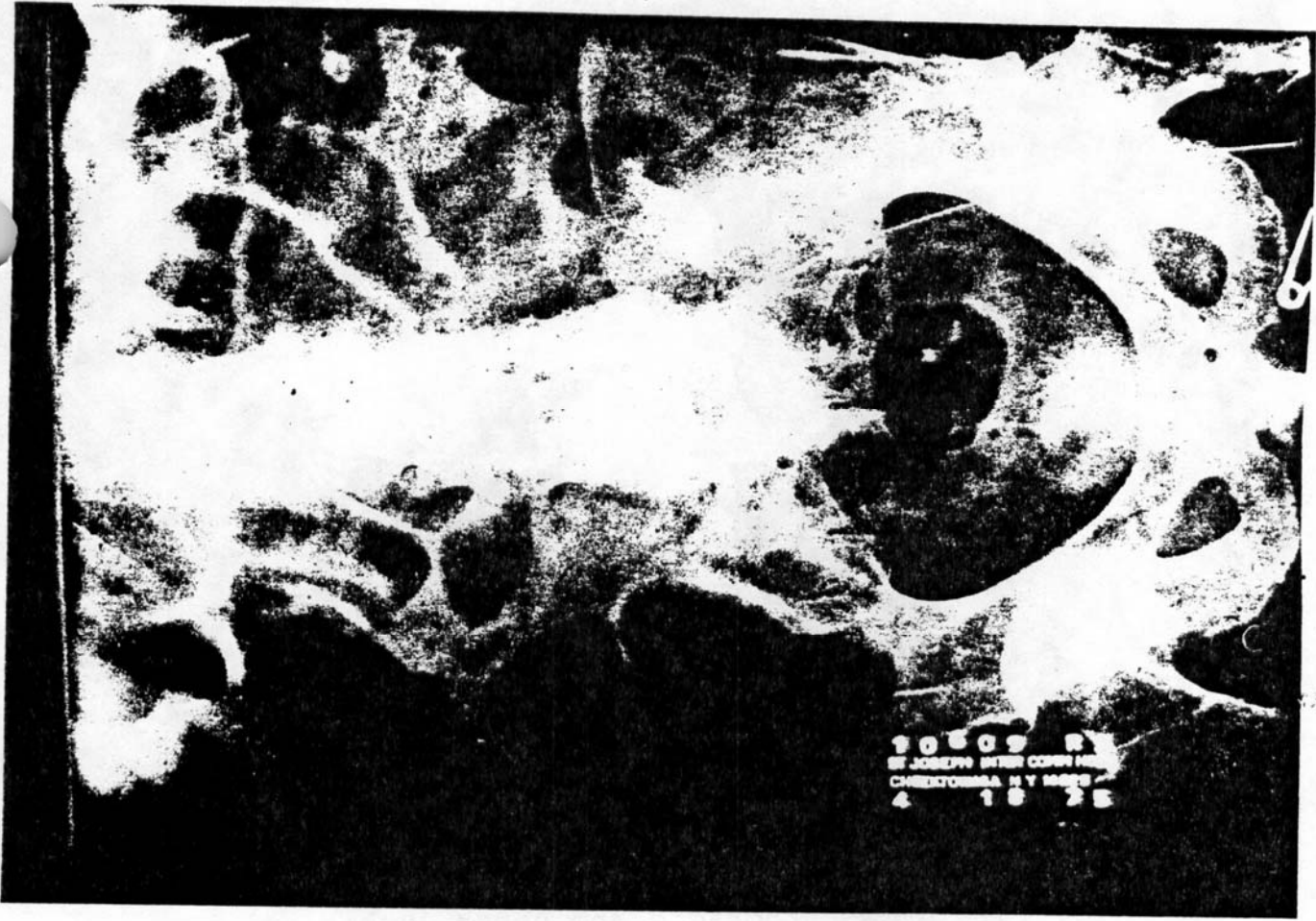multiple rib fractures (Calman 13).

Fig. 23   Lower thoracic and upper lumbar spine,
            fractures transverse processes (Calman 2).
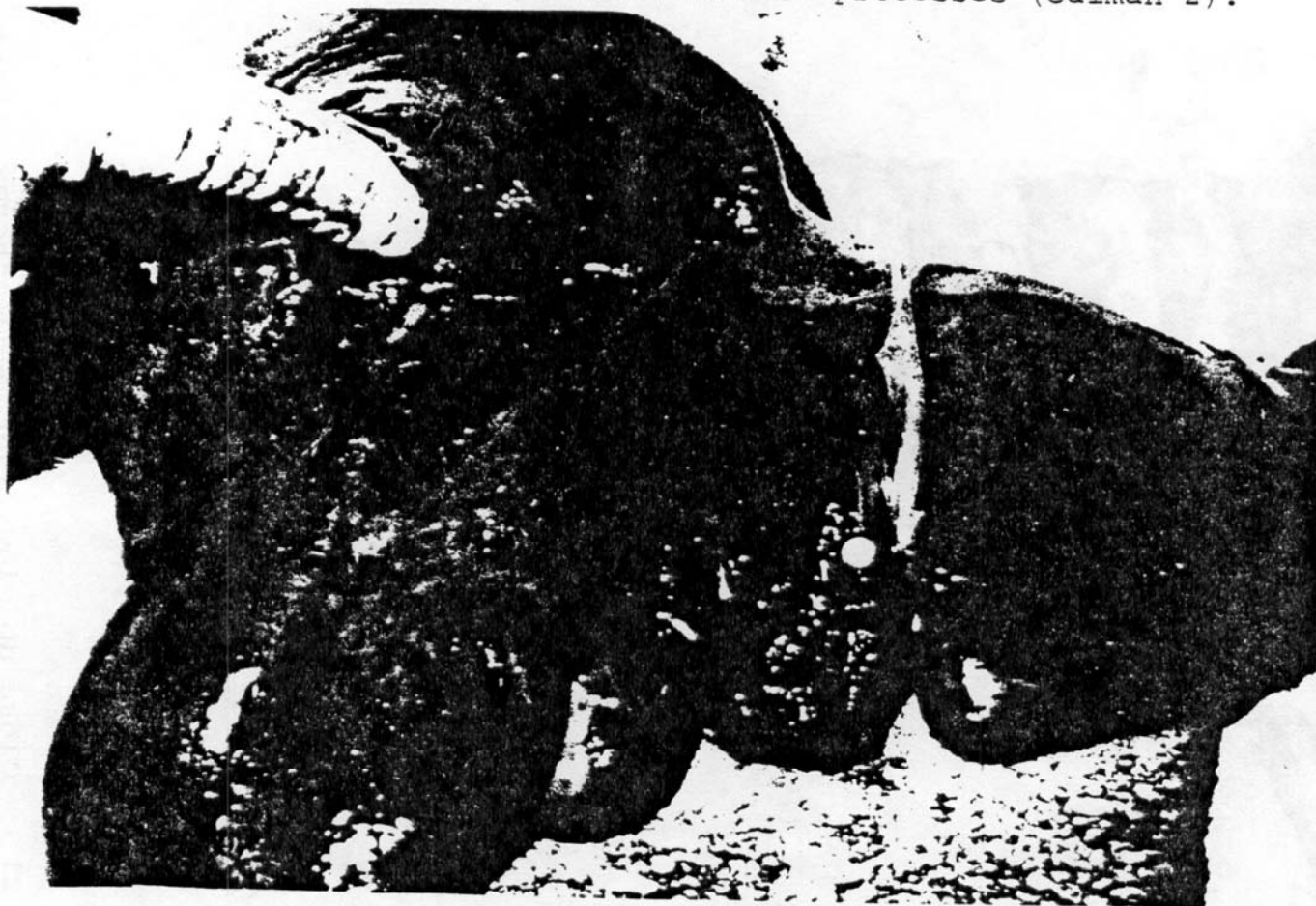

Fig. 24   Laceration of right lobe of liver (Calman 2).

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